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Dark matter distribution in the Coma cluster from galaxy kinematics: breaking the mass-anisotropy degeneracy

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ABSTRACT

We study velocity moments of elliptical galaxies in the Coma cluster using Jeans equations. The dark matter distribution in the cluster is modelled by a generalised formula based upon the results of cosmological N-body simulations. Its inner slope (cuspy or flat), concentration, and mass within the virial radius are kept as free parameters, as well as the velocity anisotropy, assumed independent of position. We show that the study of line-of-sight velocity dispersion alone does not allow to constrain the parameters. By a joint analysis of the observed profiles of velocity dispersion and kurtosis we are able to break the degeneracy between the mass distribution and velocity anisotropy. We determine the dark matter distribution at radial distances larger than 3% of the virial radius and we find that the galaxy orbits are close to isotropic. Due to limited resolution, different inner slopes are found to be consistent with the data and we observe a strong degeneracy between the inner slope α and concentration c: the best-fitting profiles have the two parameters related with $c = 19 - 9.6\,\alpha$. Our best-fitting NFW profile has concentration $c = 9$, which is 50% higher than standard values found in cosmological simulations for objects of similar mass. The total mass within the virial radius of $2.9\,h_{70}^{-1}$ Mpc is $1.4 \times 10^{15} h_{70}^{-1} M$ (with 30% accuracy), 85% of which is dark. At this distance from the cluster centre, the mass-to-light ratio in the blue band is $351\,h_{70}$ solar units. The total mass within the virial radius leads to estimates of the density parameter of the Universe, assuming that clusters trace the mass-to-light ratio and baryonic fraction of the Universe, with $\Omega_0 = 0.29 \pm 0.1$.

Key words: methods: analytical – galaxies: clusters: individual: Coma – galaxies: kinematics and dynamics – cosmology: dark matter

1 INTRODUCTION

The Coma cluster of galaxies (Abell 1656) is one of the most extensively studied in our neighbourhood (see e.g. Biviano 1998 and references therein). Starting with the seminal paper of Kent & Gunn (1982) significant effort went into dynamical modelling of the cluster. In the early studies based on about 300 galaxy velocities only velocity dispersion was modelled and it was most often assumed that the mass follows light and that the galaxies are on isotropic orbits. Merritt (1987) showed that if a larger variety of models is allowed there is a strong degeneracy between the dark matter distribution and velocity anisotropy and many models can be shown to be consistent with the data. Without any prior knowledge on the mass distribution even considering higher velocity moments would probably not be of much help.

Recently, due to theoretical progress mainly by the means of N-body simulations, our knowledge on possible dark matter distributions within gravitationally bound objects has improved significantly. There seems to be general agreement at least as to the behaviour of dark matter density profiles at large radial distances ($\varrho \propto r^{-3}$). Whether the inner dark matter density profile is $\varrho \propto r^{-1}$ (as in the so-called universal profile advocated by Navarro, Frenk & White 1997, hereafter NFW) or $\varrho \propto r^{-3/2}$ (as preferred by Moore et al. 1998; see also Fukushige & Makino 1997) or is flat (as suggested by the observed rotation curves of dwarf and low surface brightness galaxies, e.g. McGaugh & de Blok 1998) is still a matter of debate (a recent analysis by Jimenez, Verde & Oh (2003) of high resolution rotation curves of spiral galaxies shows that 2/3 of the sample can be accounted by NFW profiles, but 2/3 also with a flat core).

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